AN ASSESSMENT OF THE EDUCATIONAL POTENTIAL OF A FISHERIES MANAGEMENT SIMULATION GAME FOR ENVIRONMENTAL SCIENCES STUDENTS

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Abstract

Management simulation games have been widely used as a teaching tool. We have assessed the educational potential of Fish Banks, a role-playing interactive simulation game that allows teams to manage fish stocks through competing fishing companies. A total of 48 sessions of the game have been played during the last nine years at the Autonomous University of Madrid (Spain), as part of the practical sessions of a general undergraduate course in Natural Resources Management. Two variations were introduced in the standard game procedures that allow students to compare the time horizon of actors involved in fisheries management (short versus long term) and the presence or absence of an institution to regulate fishing management decisions. The underlying hypotheses were that long term decisions influence the rate of extraction of the resource, and that the presence of a regulatory institution has a positive effect on equity and sustainability.

Our results show that sessions run under an institutional setting had higher aggregated assets at the end of the game compared with those run for the same number of years without an institution. The fish stock at the end of the game was also higher for institution-run sessions, but the difference was less prominent. Sessions with institutions also had more evenly distributed assets among participating companies. The introduction of different models of fish population dynamics also allowed for an in-depth discussion of the role of environmental variables in natural resources management.

An assessment survey conducted among students highlighted both the pedagogic and experimental value of the game. Over 90% of the respondents agreed that it was very good for developing their analytical and critical capacities, and for improving their skills to integrate various economic, social and ecological factors into a single comprehensive framework. The fact that this could be done while they were having fun was also highly appreciated by 95% of the participants. Two thirds of the students also rated the Fish Banks practice as “better” or “much better” than the average, compared to other practical sessions of the degree program.

Keywords - Educational value, environmental sciences, fish banks, fisheries management, simulation games.

1 INTRODUCTION

Management simulation game models have been widely used as a teaching tool in the Natural Sciences. However, the full educational potential of fisheries management games has been little explored. One of the most renowned education-oriented resources is Fish Banks, a role-playing interactive simulation game developed by Meadows et al [1], supported by computer software that allows teams to manage fish stocks through competing fishing companies. Participants are requested to maximize their assets by exploiting this renewable natural resource under open access and free market competition. The two key decisions that each company has to make are changes in the size of their fleet, and allocation of fishing vessels to different fisheries.

Fish Banks has become a widely used educational resource generally aimed at high school and university curricula. Given its competition-based philosophy, the game has even been used in specialized business administration courses. Several adaptations and modifications can be found in the web, like the Stella-based application developed by the Massachusetts Institute of Technology as part of the ‘Road Maps: a guide to learning system dynamics’ project [2], or the Macromedia-based Fish Banks by University of California’s Professor W. Prothero [3]. The Fish Banks concept has even been adapted to the management of other natural resources like forests [4].

Although it was never explicitly mentioned by the authors, Fish Banks follows a conventional open access approach to fisheries management. In fact, it can be used as a tool to illustrate the effects of 'the tragedy of the commons' [3]. Indeed, the game tutorials do not mention any reference to the possibility of establishing a fisheries management institution, assuming an open access situation under strong competition that regularly leads to depletion and collapse of the resource.

However, the game doesn't preclude the establishment of institutions to regulate fisheries. With some adjustments to the procedures, the game can be played incorporating different kinds of management institutions. This approach was explored by Kolak et al [5] who developed a multi-agent model to study the Fish Banks game process, explicitly assuming the need of institutions to manage fisheries. Building on Turner [6], these authors identified five possible methods to avoid the 'tragedy of the commons' and proposed a system based on mutual coercion mutually agreed on. Under this model, the agents negotiate the right of access to the resources among themselves and jointly undertake certain coercion which prevents the collapse of the system [5]. However, the authors acknowledged the limitations imposed by the logical frame of the original Fish Banks game upon which their model is based. Moreover, their game does not compare the results with those that would have been obtained by a standard Fish Banks game session.

We have been using the Fish Banks game for nine years at the Autonomous University of Madrid (Spain), as part of the practical sessions of a general undergraduate Natural Resources Management course for students of Environmental Sciences. In this paper we explore the usefulness of the Fish Banks game as an educational tool, assessing its value to demonstrate in practice the complexities underlying natural resources management, as well as the importance of integrating a wide range of social, economical and biological issues in the decision-making process. We also used the Fish Banks game to test the theoretical hypotheses that long term decisions influence the rate of extraction of the resource, and that the presence of a regulatory institution has a positive effect on final aggregated assets, equity of income distribution, and biological sustainability of fisheries.

2 METHODS

A total of 48 sessions of the game have been played by groups of students. Each session was typically played by 16-24 students, grouped into four competing companies. Prior to the beginning of the session, the basic rules of the game were explained by the teacher, using a standardized presentation 45-50 minutes long.

A typical game session consisted in an open-access competition between fishing companies that have to decide fleet size and fishing boats allocation to two different fishing areas (high sea and littoral) with different carrying capacity, although similar population dynamics based on the logistic model. Conditions for all boats in a given year were the same, and fish prices remained constant along the game. A pseudorandom environmental factor was employed to simulate yearly population fluctuations; this factor had in fact the same pattern for all sessions. Companies had unlimited access to credit so as to expand their fleet and to cover initial running costs. A major condition of the game that influences the results is the fact that boats could not be salvaged until the end of the session. The only way for a company to reduce its fleet size was to sell boats to another company. The wining team was the one that maximised its assets (bank deposits and boat salvage value) at the end of the session. A detailed description of the game's parameters and standard playing rules can be found in Meadows et al [1].

We have introduced two variations in the standard game procedures that allow to compare the time horizon of actors involved in fisheries management (short versus long term) and the presence or absence of an institution to regulate fishing management decisions.

Twenty sessions were played using the standard Fish Banks protocol for a length of 10 years iteration. Eleven sessions were conducted under the standard protocol but extended to 15 years iteration. Seventeen sessions were conducted for a length of 10 years but asking the students to organize a fisheries management institution. Each game included three auctions of five boats that were conducted at years 1, 3, and 5. The rest of parameters (fish unit price, rates of interest, and boat salvage value at the end of the game) were set at the default option in all sessions. The length of a session (including the introductory speech) was between 3.5 and 4.5 hours, sessions with institution having regularly longer duration than those without it.

For those sessions played with a management institution, students were instructed to consider the key features of the institution they had to develop, including the aim, functioning rules, monitoring and implementation actions, and the voting and decision-making process in case of conflict. The institution,

formed by one representative of each fishing company, acted as a management board that met with an established periodicity. The decisions of this management board might include the regulation of the fleet size, catch, or access to different fisheries, as well as coercion measures such as fines or the temporary stop of the fleet. In case of unsolvable conflict between members of the board, the game manager acted as a referee who interpreted the rules previously agreed and sanctioned the most appropriate management decision.

A final plenary session with all the students allowed for a comparison of the results of the different variations of the game that were played, assessing the influence of different social, economic and biological factors in the success and sustainability of the fisheries. This was done based on a revised model built on Excel Visual Basics format that allowed for exploring the effect of varying interest rates, price-elasticity of demand, and fish population dynamics (notably, Verhulst versus Beverton-Holt population models).

To assess the students' perceptions about the pedagogic and experimental value of the game, we conducted a survey among 70 students that participated in the sessions run during 2009. An anonymous questionnaire was used to explore the usefulness of the practical sessions in developing students' skills and analytical and critical capacities, as well as to rank the Fish Banks game practice in comparison with other practical sessions that the students have had in other courses of the degree program (Table 1). An open question was also asked at the end of the questionnaire to collect students' opinion about what they considered the most remarkable features of this kind of practice, and about those unsatisfactory aspects that need to be improved.

Table 1. Type of questions used to assess the students' opinion about the educational value of the Fish Banks practical sessions.

Overall aim	**Type of questions asked**	**Answering options**
Assessing the general value of the Fish Banks practical session	It was useful from an educational point of view It facilitated the integration of social, economical and biological issues It was amusing It was amusing, but we didn't get much useful things of it It was quite boring It allowed a comprehensive analysis of the different factors behind the management of natural resources It stimulated us to develop our analytical capacities It improved our theoretical knowledge about management of natural resources	Absolutely disagree Disagree Indifferent Agree Absolutely agree
Comparing the Fish Banks practice with other practical sessions of the degree program	It was amusing It contributed to increase our analytical capacities It improved our theoretical knowledge about the topic It improved our capacities of synthesis and integration It was of educational value	Much worse than others Worse than others Like others Better than others Much better than others

3 RESULTS AND DISCUSSION

3.1 Demonstrative value of the game

The Fish Banks simulation game proved to be of high value to practically demonstrate the implications of having an institution for an adequate management of natural resources. The introduction of an institutional arrangement to manage the resource has consistently offered better results in terms of fish stocks, fish regeneration, aggregated income and egalitarian distribution of benefits.

Regarding the effect of the expected length of the activity on the sustainability and final outcome of the game, contrary to our expectations, significant differences were not found when comparing shorter versus longer term periods of resource exploitation. Unregulated open access do not seem to be very

sensitive to the expected length of their term, following similar paths whose ultimate outcome will basically depend on the point along this path that the game ends.

In the following subsections we present a comparative overview of the results regarding: (a) fisheries dynamics, (b) evolution of assets, (c) income distribution, (d) decision time, and (e) effects of changing the standard conditions of the game.

A. Fisheries dynamics

The usual team strategy during the first years of the game (when the fisheries are close to their carrying capacity) was to send most of the fleet to the high sea fishery, at least until depletion signals were evident. The higher pay-off of high sea compared to littoral explains this pattern. Then the fleet was usually moved to the littoral. Finally, if the stocks were depleted, the fleet was anchored in the harbour.

This behaviour results in a drastic reduction of high sea stocks in the early stages of the game that tend to remain at low levels although not completely exhausted, showing signs of a very slow recovery towards the end of the session. An almost complete depletion of fish in the littoral fishery followed, given its lower carrying capacity and rate of recovery. These patterns are clearly shown in the evolution of total fish captures along the session (Fig. 1).

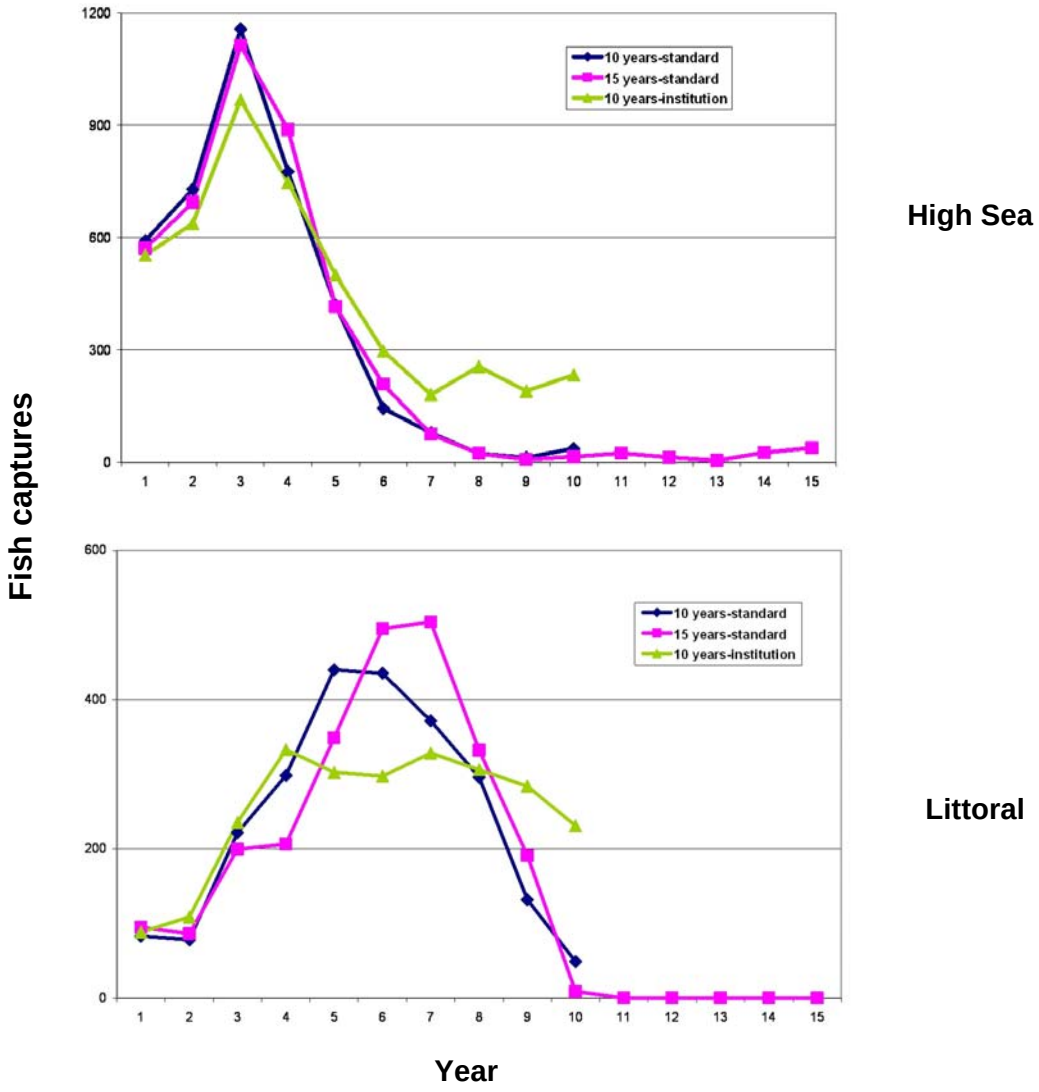

Fig. 1. Evolution of total fish captures under the three playing scenarios.

The differences found between the 10 and 15-years sessions were not statistically significant. However, when the game was played with an institution, fish stocks showed a higher level at the end of the game

as compared with the non-institutional sessions, as can be seen in the greater fish captures during the last years of the games played with institutions (Fig. 1), being these differences statistically significant. The rules adopted by the management board usually restricted the access to each fishing ground, penalizing companies that exceed their boat quotas. Under these conditions, the most common strategy consisted in spreading the fleet between high sea and littoral, and restricting the number of boats allowed to fish in each of the fishing grounds; all of which resulted in a lower fishing pressure.

As a general pattern, towards the end of the session students tended to overrule the institution by common agreement and declare it void, rushing to allocate their entire fleet to maximise benefits so as to try to win the game. This behaviour has been also observed in other institution cooperation games [7] and tends to be associated with the unrealistic assumption of a sudden and expected end of the game.

B. Evolution of assets

The averaged trend of benefits per ship along the session for the three types of game conditions is shown in Fig. 2. The first four years used to have an almost identical pattern, marked by a small initial increase followed by a fast increase while the more lucrative high sea fishing grounds are being exploited.

After the fourth year the patterns depart. On average, sessions played without an institution reached a maximum account balance per ship between years 8 and 9 of the game. Bank interests (10% benefit for positive bank deposits, 15% charge for negative bank balance) sustained a growing capital accumulation in spite of the fact that fishing resources had been depleted and the fleet had to be at the harbour, unable to obtain any income and incurring in maintenance costs. From year 9 onwards, a slight decrease in the account balance followed for both game modalities, ending in a final aggregated asset which is lower for the 15 years game modality. However, the differences between both game modalities were not statistically significant. The income generated through boat salvage value at the end of the game was included as an additional year, which explains the small increase in assets experienced in years 11 and 16 respectively.

Sessions run with an institutional regime managed to sustain a continuous increase of the account balance per ship all the way through (Fig. 2). The more regulated fishing strategy, combined with the bank interests earned, meant a continuous inflow of fish and financial-based incomes. In this case, the differences with the open access modalities were statistically significant. The four highest income sessions, each with aggregated assets above 100,000 €, were played with an institution.

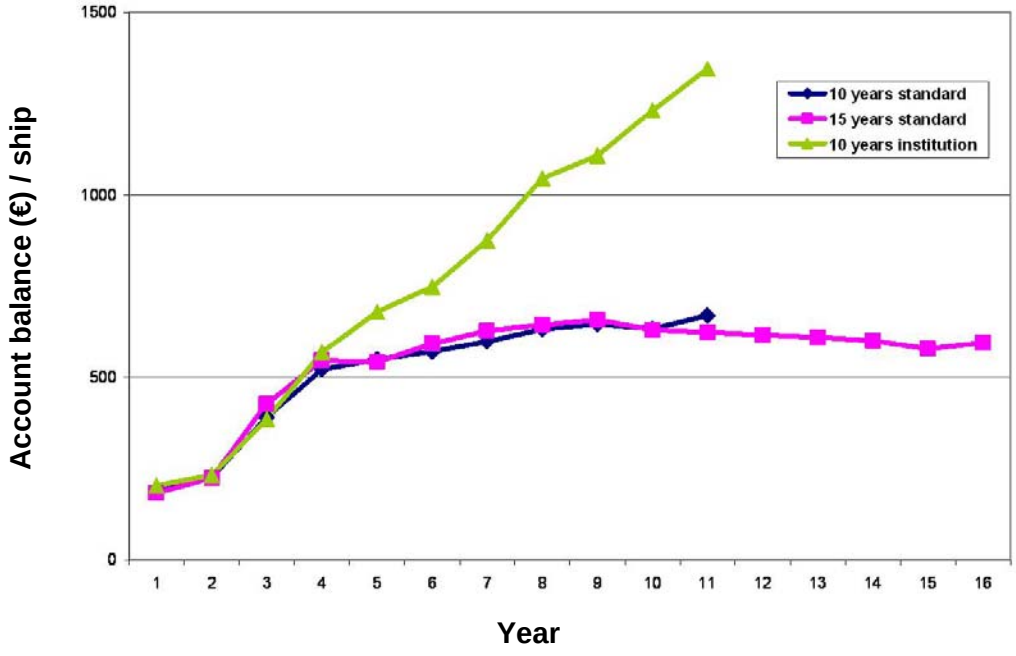

Fig. 2. Evolution of the account balance per ship under the three playing conditions.

C. Income distribution

In order to assess the differences in final income between the teams playing in each session, we developed an "income distribution index" that allowed for the inclusion of negative income (i.e. deficit) for some of the teams: Income inequality index = (largest-smallest)/largest. A low index value indicates small differences among teams (in case that the four teams of a given session had the same final assets the index would be 0), the index growing as the differences increase. The values of this index for the three playing conditions are shown in Table 2. The difference between the open access modalities was not statistically significant, whereas that of the institution and the other two was highly significant.

Table 2. Income distribution index under the three different playing conditions.

Game modality	Mean	SD	Lower and upper limits
10 years	1.16	0.96	0.71 – 1.61
15 years	2.72	4.53	0.00 – 5.77
10 years with institution	0.52	0.87	0.07 – 0.97

D. Decision time

From the educational perspective, we thought it could be interesting to analyse the evolution of the decision time along the sessions, and to see if there were differences between the three game conditions regarding this parameter. Decision time was defined as the time it took to all the four companies to make a decision on how many vessels to buy or sell, and where to allocate their fleet. Decision time followed a general pattern (see Fig. 3) that did not differ significantly between game modalities (although it has to be noted that, in those sessions run with an institution, the time spent in debates and deliberations by the management board, was not included in the calculation). The first year of the game had remarkably the longest decision times, probably associated with students' lack of experience on how the game functions. Then, a more or less continuous decrease in decision time followed until years 7-9, when a slight increase coincided with the moment of larger depletion of both fisheries. Finally, decision time showed a new continuous decrease until the end of the game when groups realized that both fisheries were depleted and the more favourable strategy was to leave boats in the harbour.

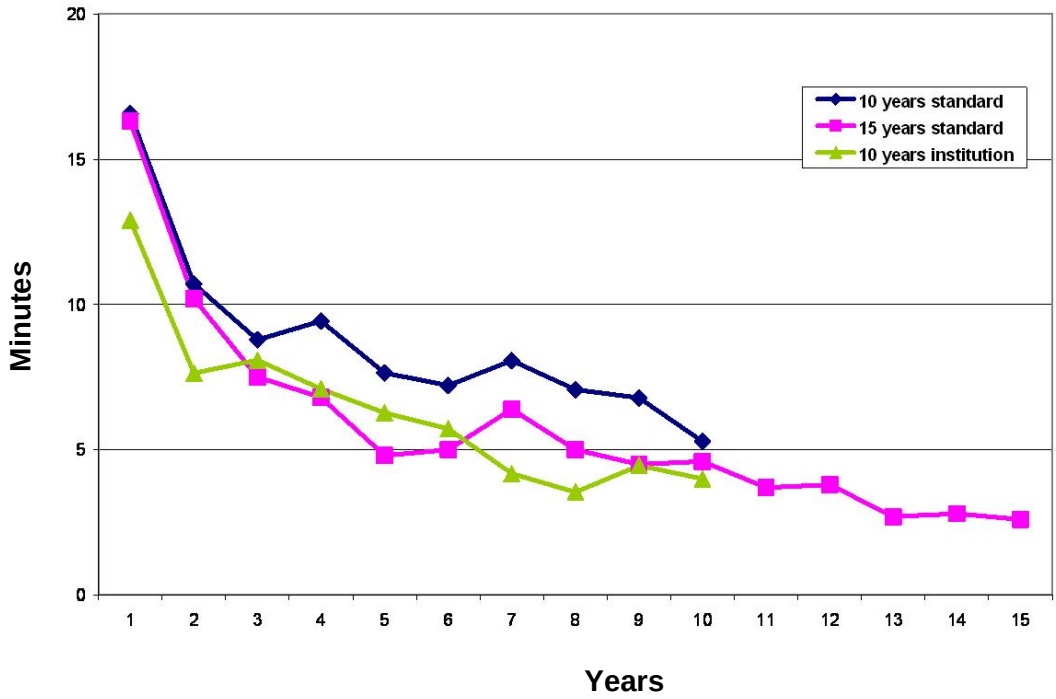

Fig. 3. Evolution of the decision time under the three playing conditions.

E. Effects of changing standard model assumptions

Three basic standard model assumptions were changed in the Excel-based models (see Table 3), and were discussed with students in plenary sessions. This allowed for exploring concepts like supply and demand, interest rate, population dynamics, and their mutual interaction. The fact that these modifications sometimes resulted in a changing of the winning or losing team makes the plenary sessions more attractive to students. As an example of the results of changing standard model assumptions, a comparison between the standard and the revised models during one particular session is shown below. The Beverton-Holt model yielded a faster recovery of fish stocks (Fig. 4). When applied to the game, it allowed for a come back of fishing opportunities in high sea and littoral grounds during the span of the game, after they have been submitted to high pressure, if one or two resting years are used. Using a demand-elastic price changed the winning and losing teams in that particular session (Fig. 5).

Table 3. Changes in the standard model conditions introduced during the plenary sessions.

Assumptions	**Standard model**	**Revised model**
Interest rate	Fixed, 10% (+ balance), 15% (- balance)	Variable, in a range of 0% to 15%
Fish price	Fixed, 20€ per unit	Variable according to different price-elasticity curves
Population dynamics	Pseudo-Verhulst	Pseudo-Verhulst, Verhulst and Beverton-Holt

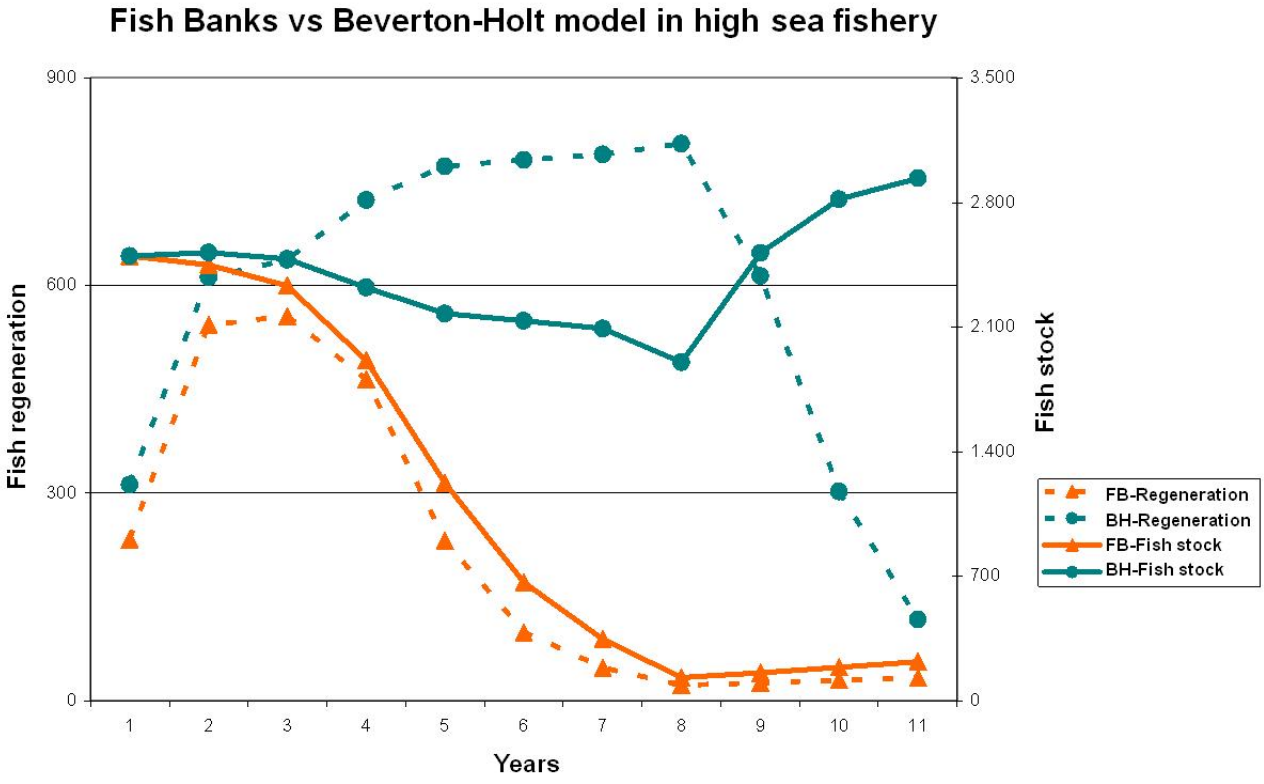

Fig. 4. Population dynamics using the Fishbanks (Pseudo-Verhulst) versus the Beverton-Holt model.

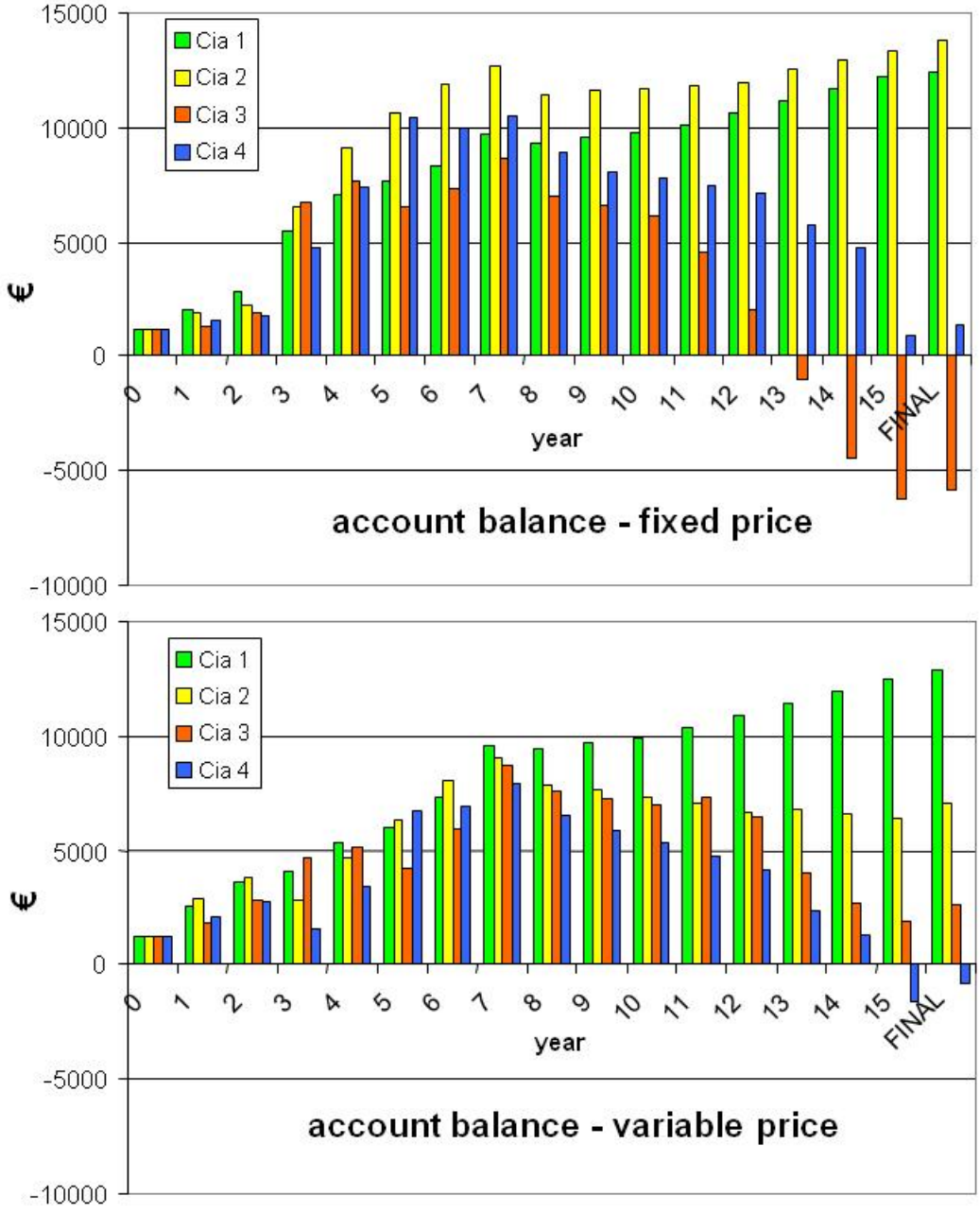

Fig. 5. Comparison of teams' account balance using fixed and elastic fish prices.

3.2 Educational value from the students' perspective

Over 90% of the respondents "agreed" or "absolutely agreed" with the value of the Fish Banks game for developing their analytical and critical capacities, and for improving their skills to integrate various economic, social and ecological factors into a single comprehensive framework. The fact that this could be done while they were having fun was also highly appreciated by 95% of the participants (see Fig. 6). Finally, there was a large agreement about the high value of Fish Banks for educational purposes (98% of the students).

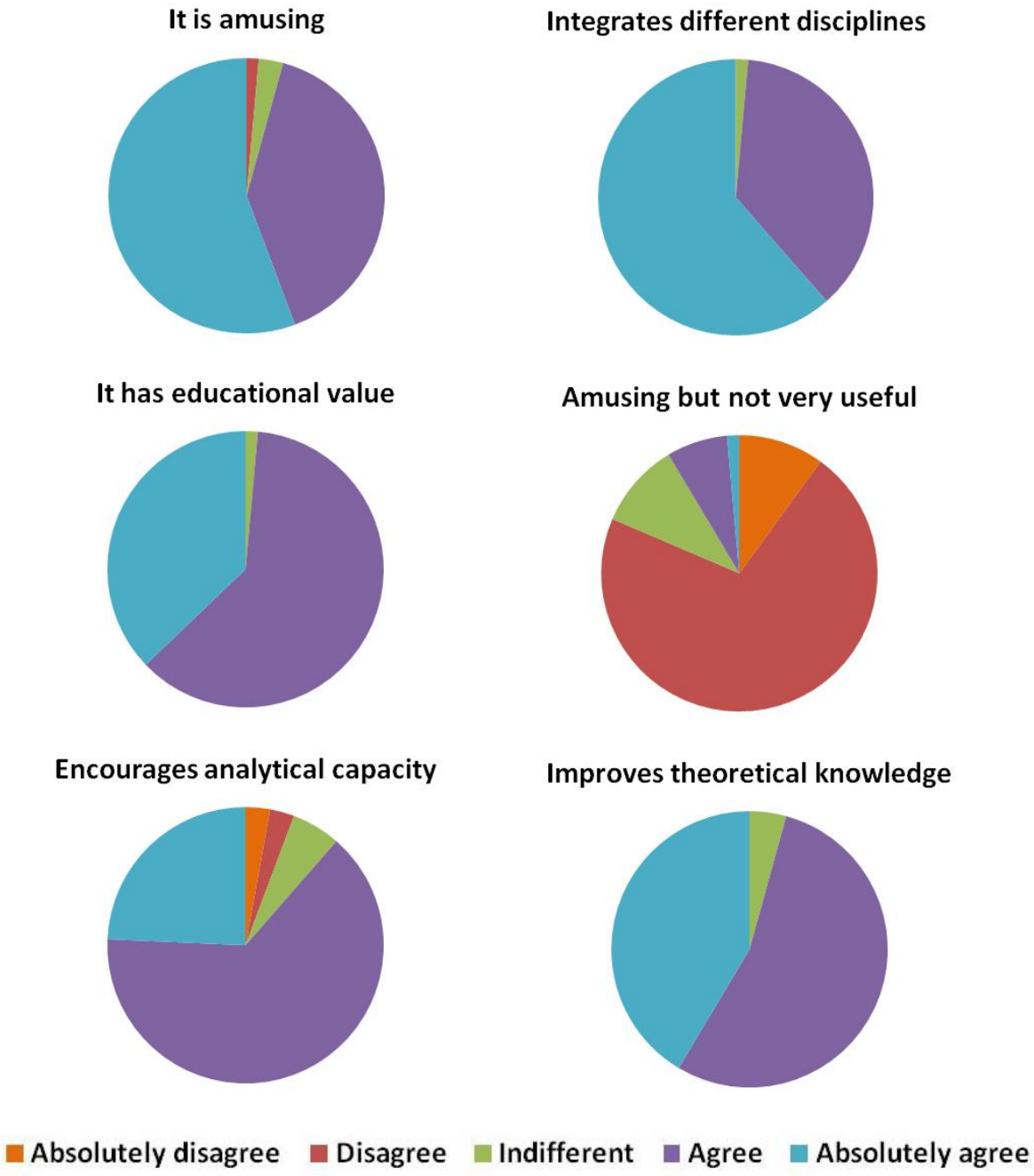

Fig. 6. Students' opinion about the educational potential of the Fish Banks practice.

Comparing some features of the Fish Banks practice with other practical sessions of the degree program also produced interesting results (Fig. 7). Two thirds of the students rated the Fish Banks practice as "better" or "much better" than the average practice sessions they had in other courses. Over 93% ranked the Fish Banks practice as more amusing than the average. The educative value of Fish Banks and its potential for encouraging students' analytical and critical capacities were also rated significantly over the average.

The answers to the open questions proposed in the survey also revealed interesting features of the students' perceptions about game. The possibility of learning and integrating different theoretical concepts while enjoying and having a good time was the most highlighted point (34% of the students), along with the fact that the game resembles quite well most of the factors behind natural resources

management in the real world (Table 4). The excessive length of the 15-year sessions, and the impossibility to modify the biological and economic variables, were the two aspects more negatively valued by students.

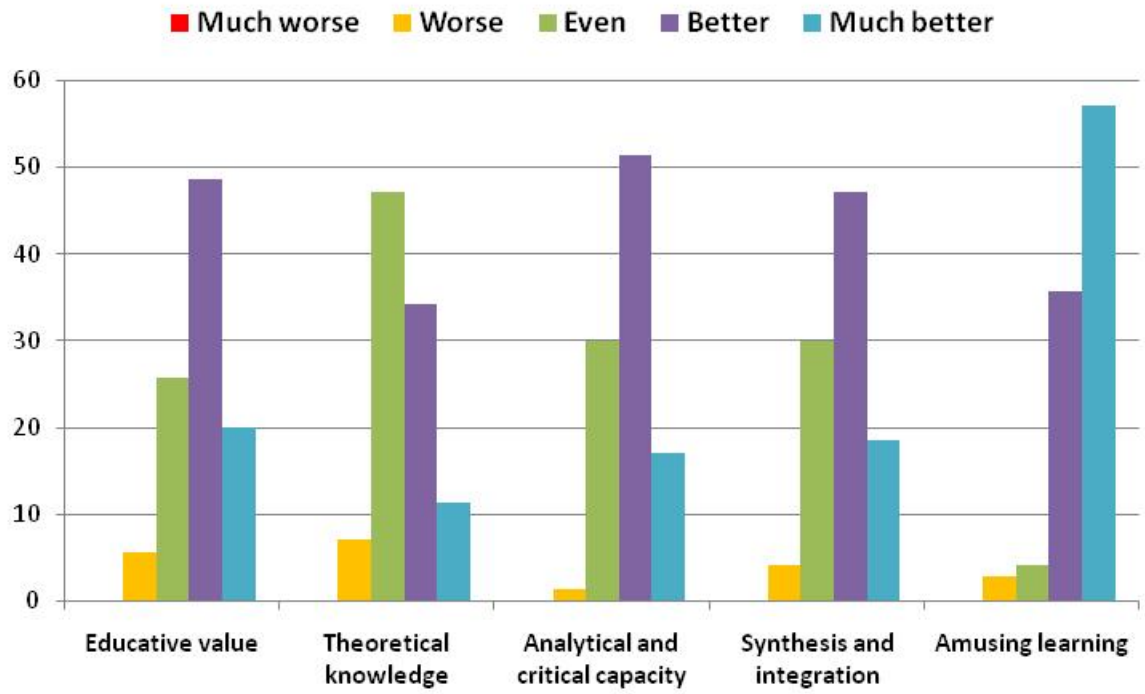

Fig. 7. Students' opinion about the Fish Banks practice compared to other practical sessions.

Table 4. Strongest and weakest features of the Fish Banks practice according to the students' opinion (figures represent percentage of students; only those points mentioned by more than 10% of the students are shown).

Most valued features of the game	Worst things that should be improved
• It is amusing and educative at the same time (34%) • The game simulation resembles quite well what happens in the real world (20%) • Good integration of ecological, social and economic aspects (17%) • It allows us to work as a team that has to discuss pros and cons before making our decisions (13%) • Original and innovative, highly different from other practices of the degree program (11%) • It enables us to put into practice many theoretical concepts acquired in the classroom (10%)	• Additional features could be included in the model (i.e., fish price varying according to captures, variable bank interests,...) • Game sessions are too long and could be reduced, particularly the 15-years session (11%) • Some key features should be explained at the beginning more thoroughly (i.e., models of fish population dynamics,...) (10%)

4 CONCLUSIONS

Our experience using the Fish Banks game as a teaching tool has been highly rewarding. Both teachers and students benefited from the “learning while having fun” approach adopted during the practical sessions.

From the teacher’s perspective, the game simulation clearly served to demonstrate in practice the critical role played by institutions in natural resources management. When compared with open access sessions, the presence of a regulatory institution allowed for better fish stock management, higher aggregated assets and lower disparity of income between teams participating in a given session. It also served to show the effects of different biological and economic assumptions on the results of the model.

On the other side, from the students’ perspective, the educational value of the game was also highly appreciated. Most of the students agreed that the Fish Banks practice was very good for developing their analytical and critical capacities, and for improving their skills to integrate various economic, social and biological factors into a single comprehensive framework. The fact that this could be done while they were enjoying was also highly valued by the participants. A large majority of the students also rated the Fish Banks practice as better than the average practical sessions they have had in other courses of the degree program.

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